COMPOSITIONS FOR TREATMENT OF MELANOMA AND METHOD OF USING SAME

This application is a continuation-in-part of US Patent Application No. 09/627,694, filed July 28, 2000, and of US Patent Application Serial No. 09/308,697 filed May 21, 1999 which is a § 371 National Phase of International Application No. PCT/US97/22669. This application claims the benefit under 35 USC § 119(e) of US Provisional Applications Nos. 60/036,419 filed February 18, 1997; 60/032,535 filed December 10, 1996 and 60/180,651 filed January 26, 2000. All of the above-mentioned applications are incorporated herein by reference.

Background of the Invention

This application relates to compositions for treatment of melanoma and to a method of using such compositions. The invention utilizes compositions containing xenogeneic differentiation antigens which are associated with melanoma to provide effective therapy.

Differentiation antigens are tissue-specific antigens that are shared by autologous and some allogeneic tumors of similar derivation, and on normal tissue counterparts at the same stage of differentiation. Differentiation antigens have been shown to be expressed by a variety of tumor types, including melanoma, leukemia, lymphomas, colorectal carcinoma, breast carcinoma, prostate carcinoma, ovarian carcinoma, pancreas carcinomas, and lung cancers. For example, differentiation antigens expressed by melanoma cells include Melan-A/MART-1, Pmel17, tyrosinase, and gp75. Differentiation antigen expressed by lymphomas and leukemia include CD19 and CD20/CD20 B lymphocyte differentiation markers). An example of a differentiation antigen expressed by colorectal carcinoma, breast carcinoma, pancreas carcinoma, prostate carcinoma, ovarian carcinoma, and lung carcinoma is the mucin polypeptide muc-1. A differentiation antigen expressed by breast carcinoma is her2/neu. The her2/neu differentiation antigen is also expressed by ovarian carcinoma. Differentiation antigens expressed by prostate carcinoma include prostate specific antigen, prostatic acid phosphatase, and prostate specific membrane antigen.

Melanocyte differentiation antigens have been shown to be recognized by autoantibodies and T cells of persons with melanoma, and to be relevant autoantigens. Wang et al., *J. Exp. Med.* 183: 799-804 (1996); Vijayasaradhi et al., *J. Exp. Med.* 171: 1375-1380 (1990). Unfortunately, in most cases, the immune system of the individual is tolerant of these antigens, and fails to mount an effective immune response. For the treatment of cancers where the tumor expresses differentiation antigens therefore, it would be desirable to have a method for stimulating an immune response against the differentiation antigen *in vivo*. It an object of the present invention to provide such a method.

Summary of the Invention

It has now been found that the tolerance of the immune system for self-derived target differentiation antigens can be overcome and an immune response stimulated by administration of a xenogeneic differentiation antigen (wild-type or mutant) of the same type from a species different from the subject being treated. For example, a mouse differentiation antigen can be used to stimulate an immune response to the corresponding differentiation antigen in a human subject. Administration of altered antigens in accordance with the invention results in an effective immunity against the original antigen expressed by the cancer in the treated subject. Thus, in accordance with a first aspect of the invention, there is provided a method for treating melanoma in a mammalian subject, comprising the step of administering to the subject an immunologically-effective amount of a xenogeneic tmelanoma-associated differentiation antigen.

Therapeutic differentiation antigens based on melanoma differentiation antigens are used in accordance with the invention to treat melanoma in subjects suffering from melanoma. In one embodiment of the invention, a plasmid comprising a sequence encoding a xenogeneic tyrosinase, for example human or murine tyrosinase, under the control of a suitable promoter, is administered to a subject. For example, dogs have been treated using plasmids comprising a DNA sequence encoding human tyrosinase with pronounced clinical benefit.

Brief Description of the Drawings

Fig. 1 summarizes the results of a tumor protection experiment using mice immunized with human gp75 expressed in Sf9 insect cells;

Fig. 2 summarizes the results of a tumor protection using mice immunized by gene gun with DNA encoding xenogeneic human gp75;

Fig. 3 shows a map and sequence of the vector htyr-pING; and

Fig. 4 shows a map and sequence of the vector mtyr-pING.

Detailed Description of the Invention

The present invention provides a method for treating melanoma in a subject by stimulating an immune response to a melanoma-associated differentiation antigen. The subject is preferably human, although the invention can be applied in veterinary applications to animal species, preferably mammalian or avian species, as well. For treatments of humans, preferred xenogeneic antigens will be rodent antigens, but could come from other mammals such as dog, cat, cow, or sheep, or from birds, fish, amphibian, reptile, insect or other more distantly related species.

As used in the specification and claims of this application, the term "immune response" encompasses both cellular and humoral immune responses. Preferably, the immune response is sufficient to provide immunoprotection against growth of tumors expressing the target differentiation antigen. The term "stimulate" refers to the initial stimulation of a new immune response or to the enhancement of a pre-existing immune response.

In accordance with the invention, a subject is treated by administering a xenogeneic differentiation antigen of the same type as a target differentiation antigen expressed by melanoma cells of the subject in an amount effective to stimulate an immune response. Thus, for example, if the target differentiation antigen is the gp75 antigen found in melanoma cells and melanocytes, the therapeutic antigen is a xenogeneic gp75 antigen.

Xenogeneic differentiation antigen may be administered as a purified differentiation antigen derived from the source organism. Proteins can be purified for this

purpose from cell lysates using column chromatography procedures. Proteins for this purpose may also be purified from recombinant sources, such as bacterial or yeast clones or mammalian or insect cell lines expressing the desired product. Nucleic acid sequences of various differentiation antigens from various non-human sources are known, including mouse tyrosinase (Yamamoto et al., *Japanese J. Genetics* 64: 121-135 (1989)); mouse gp100 (Bailin et al., *J. Invest. Dermatol.* 106: 24-27 (1996)); and rat prostate-specific membrane antigen (Bzdega et al., *J. Neurochem.* 69: 2270-2277 (1997).

Administration of the xenogeneic differentiation antigen can be accomplished by several routes. First, the xenogeneic differentiation antigen may be administered as part of a vaccine composition which may include one or more adjuvants such as alum, QS21, TITERMAX or its derivatives, incomplete or complete Freund's and related adjuvants, and cytokines such as granulocyte-macrophage colony stimulating factor, flt-3 ligand, interleukin-2, interleukin-4 and interleukin-12 for increasing the intensity of the immune response. The vaccine composition may be in the form of a xenogeneic differentiation antigen in a solution or a suspension, or the therapeutic differentiation antigen may be introduced in a lipid carrier such as a liposome. Such compositions will generally be administered by subcutaneous, intradermal or intramuscular route. Vaccine compositions containing expressed xenogeneic differentiation antigen are administered in amounts which are effective to stimulate an immune response to the target differentiation antigen in the subject. The preferred amount to be administered will depend on the species of the subject and on the specific antigen, but can be determined through routine preliminary tests in which increasing doses are given and the extent of antibody formation or T cell response is measured by ELISA or similar tests. T cell responses may also be measured by cellular immune assays, such as cytotoxicity, cytokine release assays and proliferation assays.

The xenogeneic differentiation antigen may also be introduced in accordance with the invention using a DNA immunization technique in which DNA encoding the antigen is introduced into the subject such that the xenogeneic differentiation antigen is expressed by the subject. cDNA encoding the differentiation antigen is combined with a promoter which is effective for expression of the nucleic acid polymer in mammalian cells. This can be

accomplished by digesting the nucleic acid polymer with a restriction endonuclease and cloning into a plasmid containing a promoter such as the SV40 promoter, the cytomegalovirus (CMV) promoter or the Rous sarcoma virus (RSV) promoter. The resulting construct is then used as a vaccine for genetic immunization. The nucleic acid polymer could also be cloned into plasmid and viral vectors that are known to transduce mammalian cells. These vectors include retroviral vectors, adenovirus vectors, vaccinia virus vectors, pox virus vectors and adenovirus-associated vectors. Figs. 3 and 4 show restriction maps of two tyrosinase-encoding vectors. The sequences of these vectors are given in Seq. ID. Nos. 1 and 2.

The nucleic acid constructs containing the promoter and the antigen-coding region can be administered directly or they can be packaged in liposomes or coated onto colloidal gold particles prior to administration. Techniques for packaging DNA vaccines into liposomes are known in the art, for example from Murray, ed. "Gene Transfer and Expression Protocols" Humana Pres, Clifton, NJ (1991). Similarly, techniques for coating naked DNA onto gold particles are taught in Yang, "Gene transfer into mammalian somatic cells *in vivo*", *Crit. Rev. Biotech.* 12: 335-356 (1992), and techniques for expression of proteins using viral vectors are found in Adolph, K. ed. "Viral Genome Methods" CRC Press, Florida (1996).

For genetic immunization, the vaccine compositions are preferably administered intradermally, subcutaneously or intramuscularly by injection or by gas driven particle bombardment, and are delivered in an amount effective to stimulate an immune response in the host organism. The compositions may also be administered *ex vivo* to blood or bone marrow-derived cells (which include APCs) using liposomal transfection, particle bombardment or viral infection (including co-cultivation techniques). The treated cells are then reintroduced back into the subject to be immunized. While it will be understood that the amount of material needed will depend on the immunogenicity of each individual construct and cannot be predicted *a priori*, the process of determining the appropriate dosage for any given construct is straightforward. Specifically, a series of dosages of increasing size, starting at about 0.1 ug is administered and the resulting immune response is observed, for example by measuring antibody titer using an ELISA assay, detecting CTL response using a chromium release assay or detecting TH (helper T

cell) response using a cytokine release assay. A clinical trial is being planned in which the vector mtyr-pING (Fig. 4, Seq. ID No. 2) will be administered to human subjects. In this trial, dosages of 100 μg, 500 μg and 1,500 μg will be used. Vaccination will be administered using a BIOJECTOR 2000 jet delivery device every three weeks for a total of six injections.

Once tolerance is broken through the administration of the xenogeneic differentiation antigen, subsequent treatments with syngeneic differentiation may be employed to maintain and in some cases enhance the immune response. (See, Weber, et al., "Tumor immunity and autoimmunity induced by immunization with homologous DNA." *J Clin Invest* 102 (6):1258 (1998).) Thus, in one embodiment of the invention, the subject is first treated by administration of a xenogeneic differentiation antigen (for example for three treatment cycles), and subsequently by administration of a syngeneic differentiation antigen (for example for an additional three treatment cycles). As an alternative to treatment cycles using different therapeutic agents, one can use a single therapeutic agent containing both xenogeneic and syngeneic differentiation antigens. Thus, for example, a mixture of the htyr-pING and mtyp-pING vectors, or a single vector encoding both murine and human tyrosinase under the control of a promoter such that they are expressed in a human subject can be employed for the treatment of melanoma in humans. Vectors are available commercially, for example from Stratagene and other companies, which can express two independent genes. Commonly, these vectors use an internal ribosomal entry site, or IRES, between the two genes. This approach has the advantage of requiring approval for only a single therapeutic agent.

The invention will now be further described with reference to the following, non-limiting examples.

EXAMPLE 1

C57BL/6 mice were immunized with a) syngeneic $gp75^+$ B16 melanoma cells (which express a non-mutant b locus protein); b) syngeneic B16 cells expressing IL-2, GM-CSF and IFN-γ; c) syngeneic $gp75^-$ B16 melanoma variant, B78H.1 and syngeneic fibroblasts transfected with cDNA expressing the mouse b allele; d) hydrophilic peptides of gp75 conjugated

to carrier protein; and e) full length gp75 glycoprotein purified from syngeneic melanoma cells. Cells, purified glycoprotein or peptides were combined with adjuvants, including Freund's adjuvant, a mixture of bacterial cell wall skeletons and an endotoxin derivative (DETOX), and a saponin component (QS21). Immunizations were tested by intraperitoneal, subcutaneous and intradermal routes. After immunizations, mice were assessed for antibodies against gp75 by ELISA, immunoprecipitation and Western blots, and for cytotoxic T lymphocytes (CTL) to B16 using a ^{51}Cr-release cell-mediated cytotoxicity assay. As summmarized in Table 1, no antibodies or CTL against gp75 were detected after any of these immunization strategies, supporting the conclusion that C57BL/6 maintain tolerance to the gp75 glycoprotein.

EXAMPLE 2

As shown in Example 1, syngeneic C57BL/6 mice immunized with either cell-associated or purified forms of gp75 protein did not produce autoantibodies to gp75. We next assessed whether gp75 encoded by cDNA delivered into the dermis of syngeneic C57BL/6 mice by particle bombardment would induce an autoantibody response.

C57BL/6 mice were genetically immunized with cDNA encoding full-length syngeneic gp75 under the control of a CMV promoter once a week for five weeks. Sera from these mice were then assessed for autoantibodies against gp75 by immunoprecipitation as described in the Materials and Methods. No mouse (0/28) had detectable antibodies, indicating that C57BL/6 mice maintained their tolerance to the syngeneic protein.

EXAMPLE 3

Mice were immunized with the gp75^{+} human melanoma cell line SK-MEL-19 with Freund's adjuvant and evaluated for the development of autoantibodies to murine gp75. All of the mice (20/20) developed autoantibodies. There was no response without adjuvant (0/5 mice), and no antibodies to gp75 were detected in sera of 12 mice immunized with gp75^{-} human melanomas SK-MEL-131 or SK-MEL-37 plus Freund's adjuvant. Three of five mice immunized with purified human gp75 (10 μg per dose for five immunizations) with Freund's

adjuvant developed autoantibodies to gp75, although the antibody responses were generally weaker, possibly due to the lower amount of purified gp75 used compared to the amount of gp75 in SK-MEL-19 lysates. Thus, administration of human gp75 broke the tolerance to gp75 in C57BL/6 mice.

EXAMPLE 4

B16 melanoma cells and normal melanocytes in C57BL/6 mice express GP75, the wild-type *b* allele of the *brown* locus. As described above, the product of this locus is recognized by sera from syngeneic mice immunized with mouse gp75 expressed in gp75/Sf9 cells and human gp75. We have previously shown that passive transfer of mouse monoclonal antibody against gp75 into mice bearing B16F10 tumors leads to tumor rejection. Hara et al., *Int. J. Cancer* 61: 253-260 (1995). To determine whether the autoimmune responses observed conferred similar protection against tumors, the *in vivo* effects of immune recognition of gp75 were investigated using a syngeneic tumor model.

Mice (5 mice per group) were injected subcutaneously with gp75/Sf9 lysates (5 X 10^6 gp75/Sf9 cells) concurrently with 10^5 B16F10 melanoma cells administered intravenously and the occurrence of lung metastases 14 days after tumor challenge was monitored. Mice immunized with wt/Sf9 cells and unimmunized mice were used as controls. The results are summarized in Fig. 1. As shown, mice immunized with gp75/Sf9 lysates were substantially protected against formation of lung metastases compared to the controls. Significant protection (53% decrease in lung metastases) was also observed when immunization was carried out 4 days after the tumor challenge as metastases become established. There was no significant protection in mice immunized with wt/Sf9 lysates compared to the unimmunized control.

Passive transfer of serum from mice immunized with gp75/Sf9 to five unimmunized mice produced a 68% decrease in lung metastases compared to mice treated with an equivalent amount of normal mouse serum ($p=0.02$), supporting the conclusion that tumor protection was at least partially mediated by humoral mechanisms.

Mice immunized with human gp75$^+$ SK-MEL-19 were also markedly protected against B16F10 melanoma compared to unimmunized mice. (4+/-7 metastases in immunized mice versus 275+/-77 lung metastases in control mice - 6 mice per group). Immunization with gp75$^-$ melanoma SK-MEL-131 did not introduce tumor protection against B16F10 melanoma, although recognition of other xenogeneic antigens other than gp75 could not be critically assessed.

Mice immunized against the immature, early processed form of gp75, using purified gp75 from gp75/Sf9 cells were not significantly protected against B16F10 metastases (366+/-78 metastases in four immunized mice versus 412+/-94 metastases in five unimmunized control mice). However one mouse in this group did eventually develop autoantibodies against mature gp75 and was protected against lung metastases (only 21 metastases).

EXAMPLE 5

C57BL/6 mice were genetically immunized with cDNA encoding full length human gp75 under control of the control of a CMV promoter once a week for five weeks by gene gun injection. As controls, mice were injected with full length syngeneic mouse gp75 under the control of the CMV promoter, with a glycosylation mutant of gp75 (gly31) or null DNA. Four weeks after the final immunization, the mice were injected through the tail vein with 2 X 10^5 B16F10LM3 melanoma cells. One group of treated mice were also challenged with melanoma cells. Twenty-one days after tumor challenge, mice were sacrificed and surface metastatic lung nodules were scored. There were ten mice in the untreated group, 9 mice in each of the null and mouse gp75 groups, 8 mice in the gly31 group and 19 mice in the human gp75 group. The importance of CD4, CD8 and NK cells was also tested by depletion of using monoclonal antibodies (rat mAb GK1.5 for CD4; mAb 53.6.7 for CD8 and mAb PK1.36 for NK1.1). The necessity of CD4 T cells was also assessed by looking for tumor rejection in CD4 knock-out mice after *in vivo* transfer of the human gp75 gene by gene gun.

As shown in Fig. 2, mice immunized with xenogeneic human gp75 were found to be significantly protected from lung metastases (mean 41 ± 15 metastases) when challenged with

B16F10LM3 melanoma ($p<0.0001$), with an 84% decrease in lung nodules as compared with control mice. Syngeneic mice that received *in vivo* gene transfer of the glycosylation mutant mouse gp75 were not significantly protected from B16F10LM3 tumor challenge (mean 300 ± 12 metastases), nor were those that were delivered control DNA (mean 292 ± 15 metastases) by particle bombardment or were left untreated (mean 307 ± 20 metastases) ($p>0.45$). CD8 deletion did not alter tumor rejection, although depletion of $CD4^+$ (by mAb or knock-out) and $NK1.1^+$ cells did result in a reduction in level of protection achieved. Thus these latter cells may play a role in the protection against tumors achieved using genetic immunization with xenogeneic DNA.

EXAMPLE 6

A plasmid containing a sequence encoding human tyrosinase was prepared for genetic immunization and treatment of melanoma in non-human species by introduction of cDNA encoding human tyrosinase into a pING vector. The pING vector contains the following elements: a eukaryotic promoter and enhancer from the CMV virus, a polylinker region to facilitate cloning of a variety of DNA fragments, donor and acceptor splice sites and a polyadenylation signal sequence derived from the bovine growth hormone gene, the ColE1 origin of replication and a gene conferring kanamycin resistance. With the exception of the kanamycin resistance gene, which was cloned as a Pst-I fragment from the plasmid pUC4, all other gene segments were amplified by polymerase chain reaction (PCR). The role of each segment is as follows: the CMV promoter/enhancer and intron A drive the expression of the cDNA chosen as the antigen, and that cDNA is cloned in the polylinker region. The resulting mRNA is processed and polyadenylated using the splice sites and polyadenylation signals. In order to propagate the plasmid in E. coli, the colE1 replicon and the kanamycin resistance cassette are included. The kanamycin resistance gene is cloned in the opposite orientation from the tyrosinase cDNA and therefore cannot be transcribed from the CMV promoter in human cells. The CMV promoter/enhancer in pING is fully functional *in vivo*, as shown by induction of both antibody

and cytotoxic T cell responses after DNA immunization of C57BL/6 mice with pING vector expressing tyrosinase, tyrosinase-related protein-2 and ovalbumin genes.

The 2 kb cDNA fragment encoding human tyrosinase has been previously described. Schaed, et al.. "Immunization of Melanoma Patients with both Tyrosinase (370D) and GP100 (210M) Peptides: Comparison of Adjuvants and Peptide Immunogenicity" *Proc Amer Assoc Cancer Res* 41:4029 (2000). An EcoRI fragment containing the tyrosinase cDNA was inserted into the EcoRI site in the polylinker of pING. Orientation was confirmed by bidirectional sequencing. Fig. 3 shows the resulting vector htyr-pING. The sequence of this vector is provided in Seq. ID. No. 1.

Example 7

A plasmid containing a sequence encoding murine tyrosinase was prepared for genetic immunization and treatment of melanoma in non-murine species by introduction of cDNA encoding murine tyrosinase into a pING vector. The mouse tyrosinase cDNA was obtained by reverse transcription and PCR amplification of mRNA from B16 mouse melanoma cDNA. An EcoRI fragment containing the mouse tyrosinase cDNA was inserted into the EcoRI site of the pING polylinker. A map of the resulting vector, mtyr-pING is shown in Fig. 4. The sequence of this vector is given in Seq. ID. No. 2.

EXAMPLE 8

Canine malignant melanoma (CMM) of the oral cavity, nail bed and mucocutaneous junction is a spontaneously occurring, highly aggressive metatstatic neoplasm. CMM is initially treated with aggressive surgery and/or fractionated radiation therapy, however systemic metastatic disease is quite common and invariably chemoresistant. CMM therefore appears to be a good model for advanced human cutaneous melanoma which has similar characteristics.

Three groups of three dogs reach with advanced (WHO Stage II or IV) CMM received four bi-weekly intramuscular injections (100ug, 500ug or 1500ug, respectively per

vaccination) of the htyr-pING (example 6) via the Biojector2000 jet delivery device. Pre-vaccination and intermittent post-vaccination blood samples were drawn for routine blood counts, biochemical screening, autoimmune induction and serological/T-cell responses. Minimal to mild pain was noted on vaccination in all nine dogs. No toxicity or induction of autoimmunity was seen in any of the nine dogs. One stage IV dog has had a complete clinical response of lung metastases (durable to 329 days), three dogs have had stable disease (stage III or IV; median followup > 6 months) and five dogs have been euthanized due to progression of the primary tumor. All dogs with local tumor progression had little to no local therapy prior to entrance on the study.

The following conclusion can be drawn from this study:

1. Human tyrosinase DNA vaccinations of dogs with advanced malignant melanoma is safe:
   a.No local toxicity at injection site
      i. Physical examination
      ii. Histopathological examination @ necropsy
   b.No systemic toxicity
      i. Hematological
      ii. Biochemical
      iii. ANA assay (anti-dsDNA Ab)
2. Human tyrosinase DNA vaccinations of dogs with advanced malignant melanoma appears to be therapeutic based on:
   a. Prolongation of median survival time (389 days) in comparison to historically reported median survival times (~ 150-180 days)
   b. Complete response seen in one Stage IV dog for 329 days
   c. No evidence of tumor recurrence nor metastatic disease in 2 dogs (294 & 316 days) that would be expected to not survive > 6 months
3. Canine malignant melanoma appears to be a good clinical model for advanced human melanoma as both diseases:
   a. Are spontaneous cancers

b. Occur in species in similar living environments

c. Have syngeneic tumors in the respective species

d. Are locally aggressive

e. Are widely metastatic to similar metastatic sites

f. Are chemotherapy & comparatively radiotherapy resistant